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L-SHELL BINNING AND DISPLAY OF SENSOR DATA FROM THE CRRES SPACECRAFT

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A computerized analysis system is being developed for the CRRES spacecraft to facilitate L-Shell studies of the instrument parameters over the lifetime of the vehicle. A PC-hosted graphics display system is being developed for the analysis of this data.

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1.0 OVERVIEW

The Combined Release and Radiation Effects Satellite (CRRES) payload included a number of instruments designed to provide data on particles, fields, and waves.

A Time History Data Base (THDB) for the CRRES mission was generated for each sensor on an orbit by orbit basis. This data base has been utilized for short time duration event studies as well as long term efforts involving statistical analyses and modeling efforts.

One important study for this spacecraft is the L-Shell variation of data sets over the lifetime of the mission. A technique has been developed whereby the data for selected sensors is binned into 1/20 L-Shell packets on an orbit by orbit basis. Data visualization is accomplished by the use of color spectrograms. In these visualizations, the X-Axis represents the orbit number; the Y-Axis represents the L-Shell bin; and the measured parameter is displayed in one of multiple colors for each selected band of magnitude.

The system which is being developed accesses the THDB files and generates the L-Shell binned data sets. A data visualization routine is being developed for use on the PC. Options have been incorporated into this routine to view multiple parameters from the same sensor, or compare parameters from one sensor with those of another sensor.

The sensors to be included in this system are:

- GL701-7A Relativistic Proton Detector
- GL701-7B Proton Switches
- GL701-11A Magnetospheric Ion Composition Sensor (MICS)
- GL701-11B Heavy Ion Telescope (HIT)
- ONR307-8-3 Medium Energy Ion Mass Spectrometer (IMS-HI).

The preliminary version of this system has resulted in the successful generation of spectrograms for the Relativistic Proton Detector and the Proton Switches.

This report details file structures and techniques developed for use with the Relativistic Proton Detector.

2.0 CRRES DATA FLOW

The down-linked telemetry data was recorded on instrumentation tape. The Phillips Laboratory/GPD (PL/GPD) decommutation center input the data from the instrumentation tapes and produced master-frame formatted files of the full telemetry stream. These files were placed on the PL mass storage device. The Agency Tape software accessed the master frame formatted files to produce the header files, magnetic field files, ephemeris files, attitude determination coefficient files, and the agency dependent telemetry file structures. These files were generated on an orbit by orbit basis. An orbit was defined as a spacecraft revolution about the earth starting at perigee and ending at the following perigee. The telemetry files received by each individual agency contain only the telemetry parameters required by that agency. Periodically, the agency files resident on mass storage were copied to digital tape for dissemination to the appropriate agencies. These digital tapes are referred to as Agency Tapes.

The THDB software used individual agency files as input. Once generated, the THDB were placed on the mass storage device for easy access by follow-on analysis routines.

File naming conventions were developed so that files for experiments and orbit numbers could be uniquely identified by taking a directory of the mass storage device.

2.1 GL 701-7A RELATIVISTIC PROTON DETECTOR

The objective of the Relativistic Proton Detector is to measure the energy spectra and pitch angle distributions of relativistic protons trapped in the inner Van Allen belt. The primary sensor is a Cerenkov radiator viewed by a photomultiplier tube. Two copies of this sensor with different radiators extend the energy range response. One of the radiators is an alcohol- water mixture; the other radiator is fused silica. The alcohol-water radiator has an index of refraction of 4/3 and responds to protons with energies above 440 MeV. The fused-silica radiator has an index of 3/2 and responds to protons above 320 MeV.

In addition to the Cerenkov radiators, the GL-701-7A sensor includes another detector system which measures electrons. This system consists of two detectors: an electron scatter detector (E) for electrons with energies above 200 MeV, and a heavily shielded minimum-ionizing detector (M) for penetrating electrons (>35 MeV) and protons (>80 MeV).

2.2 ANALYSIS PROCEDURES

The nomenclature for the sensor outputs is:
Alcohol (CA0-CA3)
Silica (CS0-CS3)
Electron Scatter Detector (RE(0,2) - RE(1,3))
Minimum Ionizing Detector (RM(0,2) - RM(1,3))

The counts readout by the instrument represent differential flux. They are converted to integral flux. Further, four new channels have been defined for electron integral flux for energies greater then defined levels.

For the CA, CS, RE, and RM data, the differential data is converted to integral flux as follows (where CH represents each of the 4 data sets above):

$$
\begin{aligned}
CH0' &= CH0+CH1+CH2+CH3 \\
CH1' &= CH1+CH2+CH3 \\
CH2' &= CH2+CH3 \\
CH3' &= CH3.
\end{aligned}
$$

These give integral flux values for the Cerenkov (alcohol and silica), the Electron Scatter Detector , and the Minimum Ionizing Detector.

Then, the new electron channels are defined as follows:

e > 160keV = RE0' - RM0'
e > 255keV = RE1' - RM0'
e > 460keV = RE2' - RM1'
e > 875keV = RE3' - RM2'.

The new values can be divided by the geometric factors to get integral flux.

2.3 GENERATION OF GL701-7A RELATIVISTIC PROTON SENSOR OUTPUTS AS FUNCTIONS OF L-SHELL AND B/Bo

The binning effort consists of three phases: the generation of individual files binned in 1/20th of an L-shell on an orbit by orbit basis; the generation of a single file of binned data for the lifetime of the vehicle; and the creation of files of binned data for individual periods characterized as 'quiet', 'active' and 'full' over the vehicle's lifetime. The latter files are the result of merging the 1/20th of an L-shell files with files binned by B/Bo. VAX hosted computer routines were developed to generate the files of binned data which were used in the generation of the color spectrograms.

This binning effort required the development of analysis routines for each of the three phases.

2.4 BINNING PROCESS - PHASE I

In Phase I, the 1/20th of an L-shell binning process required an automated way of obtaining the necessary input files (the sensor THDB and associated ephemeris) and generating output files (1/20th L-shell ephemeris, binned data, sum of the squares and data gap files) on an orbit by orbit basis. Therefore, an initial routine was developed to retrieve into the current directory the input files, the names of which are provided by the user. The logic allows the routine to find the required files wherever they reside, whether it be MASSTOR or a unique directory. Also, the names used for the individual output files are automatically assigned to the current directory. An interpolation routine was developed to generate an ephemeris file for a given orbit that contains a record for every 1/20th of an L-shell, thus defining the number of records and the beginning and end time for each record that is later used as a look-up table in the data processing stage. The interpolation routine, in subroutine form, computes a cubic spline interpolating table for a given orbit for all 57 ephemeris values with an entry point that returns a given value for a specified time and ephemeris index. A follow-on function was also coded which, when provided a time in seconds, returns a record number in which the current 1/20th of an L-shell binned data belongs based on the look-up table. The processing depends on a driver subroutine which accesses the sensor THDB and calls a generalized processing routine on a record by record basis. The driver unpacked and decompressed the proton counts data for each of the four integral flux channels. The routine then summed the relativistic proton counts data in the appropriate 1/20th of an L-shell bin by accessing the look-up table and associated look-up function for each time and data set. The routine also generated a data gap file based on a sigma, so chosen, as to allow approximately the same percentage of data to be discarded as was the case with other CRRES instruments, the sum of the squares output file and the actual data file based on the 1/20th of an L-shell binning. The L-shell value and the value of B/Bo were also computed in the routine by means of the spline fit interpolation routine. These values were stored in the output data file along with the number of observations in each bin.

The processing was based on filtering techniques which identified and removed 'noise points' in the raw data. Systematic filtering techniques addressed the problem of saturated data, data collected in photometer mode and data collected when the instrument was not in normal mode for other reasons. To assist in the development of analysis required for 'noise point' extraction, a PC hosted display routine for the sensor data was implemented. The routine exhibited averaged integral counts for each energy range for each sensor on an orbit by orbit basis as functions of time and selected ephemeris and magnetic field parameters. These plots proved useful in identifying the various 'noise points' in the raw data as problems arose.

The processing also included mathematical formulations associated with the Relativistic Proton Sensor which resulted in integral representations of the binned outputs. Thus, the output files associated with the phase II and phase III processing included both the differential representations of the binned data as well as the integral representations of the various data sets (refer to phase II and phase III outputs).

2.5 PHASE I OUTPUT FORMAT

The files are sequential and are comprised of a series of fixed length records. Each file contains one orbit of binned data. each record consists of 12 32-bit integer words comprised of time, L-shell, and B/Bo followed by 8 values of summed counts data based on 1/20th of an L-shell binning and the number of observations in each bin.

PHASE I DATA RECORDS - CERENKOV DETECTORS:

Word Number	Description
1	Universal time (seconds)
2	L-shell x 1000
3	B/Bo x 1000
4	CA0 summed counts - Cerenkov (Alcohol)
5	CA1 " - "
6	CA2 " - "
7	CA3 " - "
8	CS0 " - Cerenkov (Silica)
9	CS1 " - "
10	CS2 " - "
11	CS3 " - "
12	Number of observations in L-shell bin (number resides in most significant 16 bits of the 32-bit word).

PHASE I DATA RECORDS - ELECTRON SCATTER AND MINIMUM IONIZING DETECTORS:

Word Number	Description
1	Universal time (seconds)
2	L-shell x 1000
3	B/Bo x 1000
4	RE0 summed counts - Electron Scatter
5	RE1 " - "
6	RE2 " - "
7	RE3 " - "
8	RM0 " - Minimum Ionizing
9	RM1 " - "
10	RM2 " - "
11	RM3 " - "
12	Number of observations in L-shell bin (number resides in most significant 16 bits of the 32-bit word).

2.6 BINNING PROCESS - PHASE II

The phase II computer routine accessed each individual file of 1/20th of an L-shell data on an orbit by orbit basis and generated one file of binned data covering the lifetime of the vehicle. The routine was implemented twice in order to generate such a file of Cerenkov detector data and a similar file of Electron Scatter and Minimum Ionizing detector data. In both cases, the relevant 8 channels of summed counts data were individually averaged for each 1/20th of an L-shell bin.

PHASE II OUTPUT FORMAT:

The files are sequential and are comprised of a series of fixed length records. Each record of data contains one orbit of data. Each file contains 933 records, orbits 62 through 1054, exclusive of orbits 124 through 133 and 366 through 415. Each record consists of 1284 32-bit integer words comprised of 4 header words followed by 8 channels of averaged counts data repeated 160 times starting at an L-shell bin of 1-1.05, incrementing 1/20th of an L-shell to a bin range of 8.95-9.0. The 4 header words consist of orbit number, year, day of year and multiplicative factor (equal to 100), respectively.

PHASE II DATA RECORDS - CERENKOV DETECTORS (DIFFERENTIAL):

Word Number	Description
1	Orbit number
2	Year
3	Day of Year
4	Multiplicative factor=100 (divide average count values by this factor)
5	CA0 average counts for L-shell=1

6	CA1	"
7	CA2	"
8	CA3	"
9	CS0	"
10	CS1	"
11	CS2	"
12	CS3	"
13-1284	Words 5 thru 12 repeated 159 times for L-shell=1.05 to L-shell=8.95 in increments of .05.	

PHASE II DATA RECORDS - CERENKOV DETECTORS (INTEGRAL):

Word Number	Description	
1	Orbit number	
2	Year	
3	Day of Year	
4	Multiplicative factor=100 (divide average count values by this factor)	
5	CA0I = (CA0+CA1+CA2+CA3) average counts for L-shell=1	
6	CA1I = (CA1+CA2+CA3)	"
7	CA2I = (CA2+CA3)	"
8	CA3I = CA3	"
9	CS0I = (CS0+CS1+CS2+CS3)	"
10	CS1I = (CS1+CS2+CS3)	"
11	CS2I = (CS2+CS3)	"
12	CS3I = CS3	"
13-1284	Words 5 thru 12 repeated 159 times for L-shell=1.05 to L-shell=8.95 in increments of .05.	

PHASE II DATA RECORDS - ELECTRON SCATTER AND MINIMUM IONIZING DETECTORS: (DIFFERENTIAL)

Word Number	Description	
1	Orbit number	
2	Year	
3	Day of Year	
4	Multiplicative factor=100 (divide average count values by this factor)	
5	RE0 average counts for L-shell=1	
6	RE1	"
7	RE2	"
8	RE3	"
9	RM0	"
10	RM1	"
11	RM2	"
12	RM3	"
13-1284	Words 5 thru 12 repeated 159 times for L-shell=1.05 to L-shell=8.95 in increments of .05.	

PHASE II DATA RECORDS - ELECTRON SCATTER AND MINIMUM IONIZING DETECTORS (INTEGRAL):

Word Number	Description
1	Orbit number
2	Year
3	Day of Year
4	Multiplicative factor=100 (divide average count values by this factor)
5	RE0I = (RE0+RE1+RE2+RE3) average counts for L-shell=1
6	RE1I = (RE1+RE2+RE3) "
7	RE2I = (RE2+RE3) "
8	RE3I = RE3 "
9	RM0I = (RM0+RM1+RM2+RM3) "
10	RM1I = (RM1+RM2+RM3) "
11	RM2I = (RM2+RM3) "
12	RM3I = RM3 "
13-1284	Words 5 thru 12 repeated 159 times for L-shell=1.05 to L-shell=8.95 in increments of .05.

2.7 BINNING PROCESS - PHASE III

The phase III source code merged the sensor 1/20th of an L-shell binned files with those binned by B/Bo. The phase III routine assumed that the required input files were located in the working directory. A start and end orbit were read into the routine to define the merging period of interest, i.e., the 'active' period or the 'quiet' period. The routine then accessed the appropriate 1/20th of an L-shell binned files generated by phase I and binned the sensor counts data by B/Bo by means of an indexing function coded for this purpose. The resulting merged output file contains 160 records based on 1/20th of L-shell bins (binned over values 1 to 9) of sensor data binned over 20 pre-defined B/Bo values (ranging over the values .004 to 7.410). The routine was multiply executed to generate such files of Cerenkov detector data and Electron Scatter and Minimum Ionizing data.

PHASE III OUTPUT FILE:

The files are sequential and are comprised of a series of fixed length records. Each record of data contains averaged data for a discrete 1/20th of an L-shell bin. Each file contains 160 records (based on 1/20th of L-shell bins with a range of 1 to 9) of averaged sensor counts data binned over 20 pre-defined B/Bo values (ranging from 1.004 to 7.410). Each record consists of 181 32-bit integer words comprised of the record #, 8 channels of summed counts data for 20 pre-defined B/Bo intervals (a total of 160 such sums followed by 20 corresponding numbers of observations in each B/Bo bin.

PHASE III DATA RECORDS - CERENKOV DETECTOR (DIFFERENTIAL):

Word Number	Description
1	Record # (1 thru 160)
2	CA0 Summed counts - for 1.004 < B/Bo < 1.02
3	CA1 " - "

4	CA2 " - "
5	CA3 " - "
6	CS0 " - "
7	CS1 " - "
8	CS2 " - "
9	CS3 " - "
10-161	Words 2-9 repeated 19 times for remaining B/Bo intervals ranging from 1.02 to 7.410.
162	# of observations in bin 1.004 < B/Bo < 1.02
163-181	# of observations in remaining B/Bo intervals. intervals ranging from 1.02 to 7.410.

PHASE III DATA RECORDS - CERENKOV DETECTOR (INTEGRAL):

Word Number	Description
1	Record # (1 thru 160)
2	CA0I = (CA0+CA1+CA2+CA3) Summed counts - for 1.004< B/Bo <1.02
3	CA1I = (CA1+CA2+CA3) " - "
4	CA2I = (CA2+CA3) " - "
5	CA3I = CA3 " - "
6	CS0I = (CS0+CS1+CS2+CS3) " - "
7	CS1I = (CS1+CS2+CS3) " - "
8	CS2I = (CS2+CS3) " - "
9	CS3I = CS3 " - "
10-161	Words 2-9 repeated 19 times for remaining B/Bo intervals ranging from 1.02 to 7.410.
162	# of observations in bin 1.004 < B/Bo < 1.02
163-181	# of observations in remaining B/Bo intervals. intervals ranging from 1.02 to 7.410.

PHASE III DATA RECORDS - ELECTRON SCATTER AND MINIMUM IONIZING DETECTORS (DIFFERENTIAL):

Word Number	Description
1	Record # (1 thru 160)
2	RE0 Summed counts - for 1.004 < B/Bo < 1.02
3	RE1 " - "
4	RE2 " - "
5	RE3 " - "
6	RM0 " - "
7	RM1 " - "
8	RM2 " - "
9	RM3 " - "
10-161	Words 2-9 repeated 19 times for remaining B/Bo intervals ranging from 1.02 to 7.410.
162	# of observations in bin 1.004 < B/Bo < 1.02
163-181	# of observations in remaining B/Bo intervals. intervals ranging from 1.02 to 7.410.

PHASE III DATA RECORDS - ELECTRON SCATTER AND MINIMUM IONIZING DETECTORS (INTEGRAL):

Word Number	Description
1	Record # (1 thru 160)
2	RE0I = (RE0+RE1+RE2+RE3) Summed counts - for 1.004< B/Bo <1.02
3	RE1I = (RE1+RE2+RE3) " - "
4	RE2I = (RE2+RE3) " - "
5	RE3I = RE3 " - "
6	RM0I = (RM0+RM1+RM2+RM3) " - "
7	RM1I = (RM1+RM2+RM3) " - "
8	RM2I = (RM2+RM3) " - "
9	RM3I = RM3 " - "
10-161	Words 2-9 repeated 19 times for remaining B/Bo intervals ranging from 1.02 to 7.410.
162	# of observations in bin 1.004 < B/Bo < 1.02
163-181	# of observations in remaining B/Bo intervals. intervals ranging from 1.02 to 7.410.

2.8 GENERATION OF COLOR SPECTROGRAMS OF BINNED GL701-7A RELATIVISTIC PROTON SENSOR OUTPUTS

A PC hosted set of display utilities which access the phase III data files was developed to generate a color spectrogram representation of the Relativistic Proton data as a function of L-shell and B/Bo for each of the instrument channels. The program has options for linear or log representation and variable intensity scales based on color coding. The summed counts values were averaged in this plotting routine. These interactive graphics routines proved useful in the analysis of the flight data.

Additionally, a generalized PC-hosted particle display utility which accesses the phase II data files was developed to create spectrograms of selected CRRES sensor outputs as functions of L-shell and orbit number. A description of this display utility's capabilities follows.

CRRES PARTICLE DISPLAY UTILITY

The CRRES Particle Display Utility is a PC-hosted code which can provide:

- color imaged spectrograms of particle data as a function of orbit and L-shell, over the vehicle lifetime or for an arbitrary range of orbits (with the option of excluding selected 'noisy' orbits);
- displays of particle data as a function of L-shell, for arbitrary orbits;
- displays of particle data at a specified L-shell over a range of orbits (with the option of excluding selected 'noisy' orbits).

The Display Utility can be used to view up to five data channels simultaneously, for data set-to-data set overviews and channel-to channel comparisons. The color imaging (spectogram) format of these displays facilitates rapid assessment of the gross features of the data, and the ability to display several channels simultaneously allows for rapid correlation of features between data sets.

Once an overview display is generated, one may generate profiles of particle data versus L-shell for a given orbit, or particle data versus orbit for a given L-shell. Data channels may be arbitrarily selected from the existing data files.

The Display Utility supports menu selection of the data sets and channels to display, and permits mouse-driven selection of fixed L-shells and fixed orbits in the profile displays.

The various data sets the utility can display are defined in an index file containing the data set descriptors, the file names (and, implicitly, their storage locations), the number of data channels per file, and individual channel descriptors. This index file is a text file, and is readily extensible as the numbers and types of data files evolve: thus the capabilities of the display utility are not limited to the currently-defined data sets.

The data files themselves may be downloaded to a PC host through the PATHWORKS utility, or they may remain on the VAX, in which case the Display Utility accesses them through PATHWORKS at run-time. In either case, the usual tradeoffs between disk-storage and access time apply. PC-resident data sets are rapidly accessed, but the files are large and may be inconvenient to store (the currently-defined data sets consume approximately 40 Megabytes of disk space), while the access time for the VAX-resident files is generally slower than for PC-resident files, although performance is dependent on network traffic. A mixed-mode storage scheme is also possible, in which the data sets are distributed over both platforms in such a way that the more-frequently accessed files reside on the PC while the remainder are available through PATHWORKS.

In addition, the display program has the capability of utilizing the components of the integral representations (in the case of the Relativistic Proton Background Scatter and Minimum Ionizing sensors) in the computation and display of the following formulations:

For electrons	> 160 kev	(RE0I-RM0I)/G1
"	> 255 kev	(RE1I-RM0I)/G2
"	> 460 kev	(RE2I RM1I)/G3
"	> 875 kev	(RE3I-RM2I)/G4.